

# UK Patent Application (19) GB (11) 2 170 003 A

(43) Application published 23 Jul 1986

(21) Application No 8527771

(22) Date of filing 11 Nov 1985

(30) Priority data

(31) 8431210

(32) 11 Dec 1984

(33) GB

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G01N 23/08 G01T 1/167 G21C 17/06

(52) Domestic classification (Edition H):

G1A A12 A1 A2 BG C12 C1 D10 G10 G12 G13 G17 G1  
G3 G5 G6 MS R2 S11 S6 T15 T20 T3 T8 T9

B8A 4G1B 4LJ 4K2A

G6C DD DX

U1S 1906 2144 2146 2162 2185 B8A G1A G6C

(56) Documents cited

None

(58) Field of search

G1A

G6C

G6P

Selected US specifications from IPC sub-classes G01N

G01T G21C

(54) Improvements in or relating to methods and apparatus for testing nuclear reactor fuel pins

(57) A nuclear reactor fuel pin is passed by a nip roller assembly, Figure 6, between a source of radiation 50 and a detector 51 and the lengths of successive fuel pellets in the pin is derived from the output of the detector (eg the peaks between pellets) and the pin speed. The pin is moved in steps past a further detector 52 of naturally occurring radiation from the fuel to obtain an indication of the enrichment level at positions spaced along the pin. A comparison of the detector outputs with control values enable a pin to be accepted or rejected.

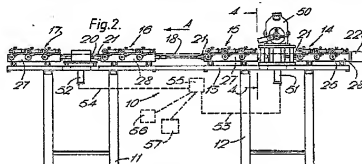
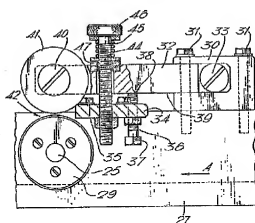


Fig. 6.



GB 2 170 003 A

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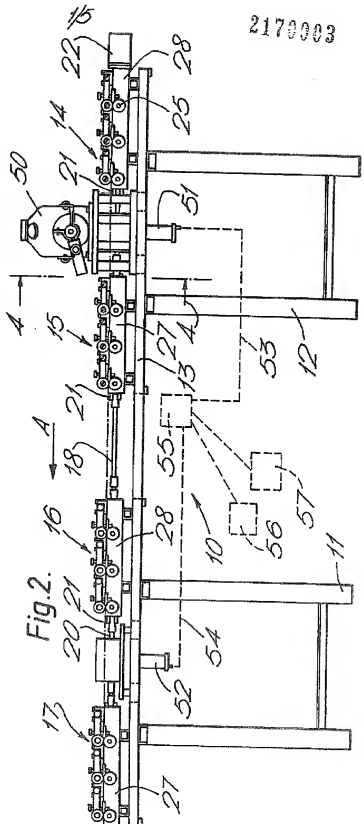
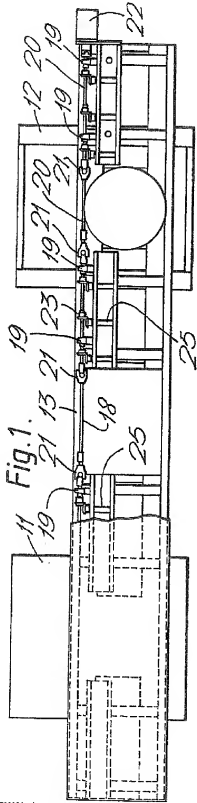
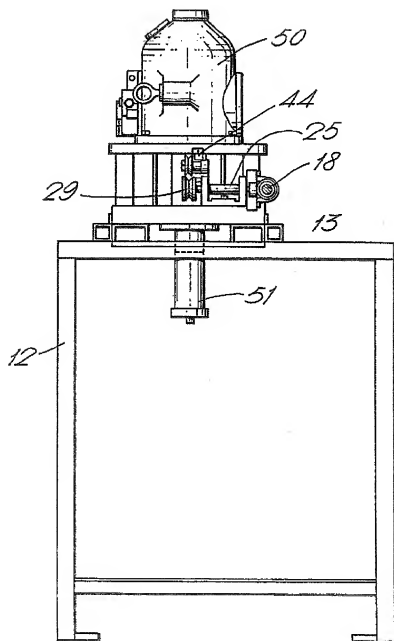


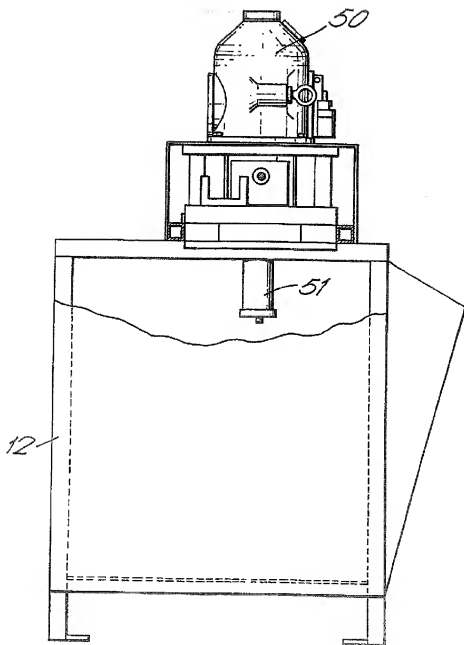
Fig. 3.



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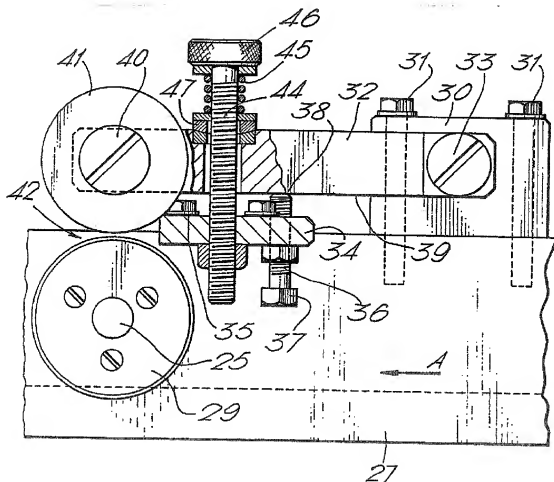
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Fig . 4.





*Fig. 6.*



## SPECIFICATION

**Improvements in or relating to methods and apparatus for testing reactor fuel pins.**

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This invention relates to methods and apparatus for testing nuclear reactor fuel pins.

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According to one aspect of the invention a method of detecting the enrichment level at a plurality of positions along the pin by sending naturally occurring radiation from fuel in the pin, and comparing the sensed radiation with a predetermined value.

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The method may comprise sensing at each position the total amount of said radiation in a predetermined period from a predetermined length of the pin. The radiation may be gamma radiation. At least one of the fuel pellets in the pin may be doped with neutron absorbing additive.

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The method may comprise passing the pin between a source of radiation and a detector for the radiation, and deriving from the detector output and the speed of the pin a measure of the lengths of successive fuel pellets in the pin. The measure may be derived from peaks in detector output occurring at junctions between successive pellets.

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According to another aspect of the invention apparatus for testing fuel pins for nuclear reactor comprises means for sensing naturally occurring radiation from fuel in the pin, means for comparing the sensed radiation with a predetermined value, and means for moving the pin past the sensing means so as to detect enrichment level at a plurality of positions along the pin.

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The sensing means may be operative to sense the total amount of said radiation in a predetermined portion of the length of the pin in a predetermined time. The radiation may be gamma radiation.

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The apparatus may include a source of radiation, a detector for the radiation, the pin being arranged to pass between the source and the detector, and means for deriving from the detector output and the speed of the pin a measure of the lengths of successive fuel pellets in the pin.

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There may be means for indicating whether the lengths of the pellets in the pin correspond to a predetermined pattern.

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The means for passing the pin may be adapted to bring a plurality of selected pellets in succession into operative relation with said radiation responsive means.

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The invention may be performed in various ways and one specific embodiment with possible modifications will now be described by way of example with reference to the accompanying drawings, in which:-

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Figure 1 is a plan view of a nuclear reactor fuel pin checking apparatus with part omitted;

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Figure 2 is a side view of Figure 1;

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Figure 3 is an end view from the right of Figure 1 on a larger scale with part omitted;

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Figure 4 is a view essentially on the line 4-4 of Figure 1 on a larger scale;

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Figure 5 is a plan view of part of Figure 1 with part horizontal section and on a larger scale; and

Figure 6 shows a side view of part of Figure 5, with part in section and on a larger scale.

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Referring to the drawings, the apparatus 10 is arranged for checking the fuel pins for a nuclear reactor. Each fuel pin contains a row of fuel pellets in an elongate can or container.

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It is known to select the length of a fuel pellet to represent a particular level of enrichment; and for discrete zones of a fuel pin to be occupied by pellets of the same length (enrichment) so that the pellets in different zones have different lengths.

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The apparatus comprises spaced platforms 11, 12 supporting a table 13 which supports drive units for moving a fuel pin in the direction of the arrow A.

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Drive units 14, 15, 16, 17 are shown and are basically similar and will be described mainly with reference to Figure 5. A drive shaft 18 extends generally the length of the apparatus and is rotatable in bearings in supports 19. The shaft 18 is in lengths such as 20 connected by universal couplings such as 21. The shaft 18 is rotatable by a stepper motor 22.

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The shaft 18 carries spaced bevel gears 23 respectively co-operable with bevel gears 24 at the ends of transverse shafts 25 which are rotatable in bearings 25a in upstanding flanges 26, 27 of channel members 28. At their other ends the shafts 25 carry V-groove rollers 29. Adjacent each roller 29 a block 30 is secured by bolts 31 to flange 27 and an arm 32 is pivoted to the block 30 at 33. A plate 34 is secured to the flange 27 by bolts 35, spaced from block 30. A bolt 36 with head 37 is in threaded engagement in a bore in the plate 34 and has an upper end 38 engageable with the underface 39 of the roller 32. At its outer end the arm 32 rotatably receives a shaft 40 carrying a V-groove roller 41 of slightly smaller diameter than the associated roller 29 and defining with that roller a passage 42 for the fuel pin under test on path 43. An adjusting screw 44 in a threaded engagement in the plate 34 and a helical spring 45 extends between the head 46 of screw 44 and a seating washer 47 in the arm 32. Thus the roller 41 is biased towards the roller 29, the bias being adjustable by screw 44, and the bolt 36 acts as an adjustable limit stop for the movement of the roller 41 towards the roller 29. The spring 45 can yield to accommodate variations in fuel pin diameter.

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A source 50 (not shown in Figure 1) of gamma rays, for example Cs137, is located above the path 43 on platform 12 and a gamma ray detector 51 is mounted below the source 50 and below the path 43.

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Another gamma ray detector 52 is mounted beneath table 13 between drive units 16, 17.

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In use, a fuel pin is driven through the machine by the stepper motor 22, the pin moving on the path 43 between and engaged in rollers 29, 41 the pin at all times being gripped by at least two pairs of said rollers.

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The outputs from the detectors 51, 52 go respectively on lines 53, 54 to a microprocessor 55 which can output to a visual display unit 56 and a printing machine 57.

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The pin is entered into the machine and then automatically aligned to a datum position on the end cap, by a photosensor. The pin is then fed into the apparatus at a constant pre-set average speed,

traversing between gamma ray source 50 and detector unit 51.

Thus using source 50 the detector 51 continuously responds to radiation from the source and the microprocessor accumulates the counts from the detector, for example every 100MS. The counts are stored in the memory of the computer and are compared with pre-set control levels by the microprocessor. The ends of the pellets are dimpled and at the interface of junction between two successive pellets the  $\gamma$ -ray transmission is much greater and so the count is greater. The number of samples taken between two successive end counts, correlated with the speed of the pin, give a measure of the length of the pellet. The number and lengths and order of pellets in the pin as indicated by the detector are compared in the microprocessor with a number of acceptable pellet arrangements and if not found to correspond to one of these, the REJECT indication is given.

If there is a gap, say more than 0.25mm, between adjacent pellets, the signal from the detector indicates a high and relatively long peak and this also produces a REJECT indication from the microprocessor.

If no REJECT indication is given, the pin then passes to detector 52 to check the enrichment, as above. This part of the process is completed in approximately 280 seconds.

The pin is now in position for the first enrichment level check. The enrichment level is checked at four (for example) spaced positions along the pin. The naturally occurring radiation from a fuel pin length of approximately 55mm is detected by detector 52 and the total count accumulated in a 60 second period stored in microprocessor memory. The pin is then accelerated and decelerated to the next static checking position and the procedure repeated along the length of the pin, eg. at four positions, corresponding to the centre of upper and lower enrichment zones and two positions equispaced between. (The same four positions are used for a single enrichment pin.) The stored counts from the selected portions of pin length are then compared with preset control levels and if any count lies outside the acceptable range, a REJECT indication is given. The four enrichment level checks are completed in approximately 250 seconds.

The microprocessor then combines the results of all the various checks and determines whether the pin conforms to an acceptable design, the result being printed out onto a fuel pin sheet. If the pin is acceptable, the enrichment type is printed, along with the date and the word ACCEPT. The fuel pin is then automatically released. If the fuel pin is not acceptable, the error type(s), the date and the word REJECT are printed. In this case the pin is held in the apparatus and can only be released by attaching the keyboard to the VDU and keying in a letter requested on the VDU 56.

The equipment is on continuous track for both enrichment checking and pellet length/gap detection, with restricted access to the fuel pin once it is within the apparatus.

The apparatus is calibrated using a test fuel pin

having a known mixture of long and short pellets of, say, 1.8%, 2.6% and 3.2% U235 enrichment, interspaced at certain locations by five spacers to produce pellet to pellet interface gaps. The comparison is visually available at 56 and printed at 57 so that an operator can see when a reading is outside a permitted tolerance from the test value.

The apparatus is particularly of use for inspecting fuel pins in which at least one of the fuel pellets is doped with, ie. contains, one or more neutron absorbing additive, for example gadolinia.

## CLAIMS

1. A method of testing fuel pins for nuclear reactors comprising detecting the enrichment level at a plurality of positions along the pin by sensing naturally occurring radiation from fuel in the pin, and comparing the sensed radiation with a predetermined value.

2. A method as claimed in Claim 1, comprising sensing at each position the total amount of said radiation in a predetermined period from a predetermined length of the pin.

3. A method as claimed in Claim 1 or Claim 2, in which the radiation is gamma radiation.

4. A method as claimed in any preceding claim, in which at least one of the fuel pellets in the pin is doped with a neutron absorbing additive.

5. A method as claimed in any preceding claim, comprising passing the pin between a source of radiation and a detector for the radiation, and deriving from the detector output and the speed of the pin a measure of the lengths of successive fuel pellets in the pin.

6. A method as claimed in Claim 5, in which the measure is derived from peaks in detector output occurring at junctions between successive pellets.

7. Apparatus for testing fuel pins for a nuclear reactor comprising means for sensing naturally occurring radiation from fuel in the pin, means for comparing the sensed radiation with a predetermined value, and means for moving the pin past the sensing means so as to detect enrichment level at a plurality of positions along the pin.

8. Apparatus as claimed in Claim 7, in which the sensing means is operative to sense the total amount of said radiation in a predetermined portion of the length of the pin in a predetermined time.

9. Apparatus as claimed in Claim 7 or Claim 8, in which the radiation is gamma radiation.

10. Apparatus as claimed in any of Claims 7 to 9, including a source of radiation, a detector for the radiation, the pin being arranged to pass between the source and the detector, and means for deriving from the detector output and the speed of the pin a measure of the lengths of successive fuel pellets in the pin.

11. Apparatus as claimed in Claim 10, including means for indicating whether the lengths of the pellets in the pin correspond to a predetermined pattern.

12. Apparatus for testing fuel pins for a nuclear reactor substantially as hereinbefore described with reference to and as shown in the accompanying



drawings.

13. A method of testing fuel pins for a nuclear reactor substantially as hereinbefore described.

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Printed in the UK for HMSO, D9818236, 8/86, 7102.  
Published by The Patent Office, 25 Southampton Buildings, London,  
WC2A 1AY, from which copies may be obtained.

